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This annual report summarizes project activity from September 29, 2005 through April 28, 2006. All deliverables for this project period were met:

• PACS equipment became fully operational at all four community hospitals (Eupora, Pontotoc, West Point, and Iuka sites)

• Radiology staff at all four sites were thoroughly training • Data collection and analysis continued with results reported

• Network vulnerability assessment and penetration tests were completed with results reported

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Introduction

The project period encompasses the second phase of a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at North Mississippi Medical Center's (NMMC) main hospital campus in Tupelo, four community hospitals in northeastern Mississippi, and at 15 clinics and to test relevant research hypotheses pertaining to quality, security, and clinical issues. Phase I involved 1) installation of PACS equipment secured with Army Security Architecture for Medical (ARSAM) Systems Design Plan on all freestanding buildings on the NMMC campus, including NMMC-Tupelo, Women's Health Center, Longtown Imaging, Digestive Health, Internal Medicine Associates, and the Cancer Center, 2) training of NMMC's radiologists, and 3) design of research database. Phase II deliverables included 1) installation of PACS equipment secured with ARSAM Systems Design Plan at four community hospitals in northeastern Mississippi, 2) training of all radiology staff members at these facilities, 3) multiple tests of security architecture, and 4) collection and analysis of efficiency, satisfaction, and outcome data.

Body

Two years ago, NMMC, in conjunction with its health system, North Mississippi Health Services (NMHS), proposed a three-phase initiative to install Picture Archiving and Communication Systems (PACS) and Teleradiology at its main hospital campus, four community hospitals in northeastern Mississippi, one community hospital in northwestern Alabama, and at 15 clinics. In addition to improving the quality of radiology services for people living in this rural region, including military personnel, military reserve personnel, and military dependents, the PACS systems would be used to test security architecture for networked medical devices, an initiative of critical importance to the military, and to research clinical outcomes associated with PACS technology that are of significance to the military and other health care operations.

The hypotheses to be tested were that implementation of state-of-the-art PACS on the NMMC-Tupelo campus, four community hospitals, and other sites affiliated with the NMHS system will 1) improve radiology efficiency, 2) improve clinical outcomes, and 3) demonstrate that networked PACS can be made secure to intrusion and device compromise.

Expected results of the initiative included:

1) Increased efficiency of radiologists as measured by performance indicators
2) Decreased number of radiology support staff (film librarians and technicians)
3) Increased satisfaction of radiologists, other medical providers, and patients as measured by satisfaction surveys (medical staff, radiologists, and consumers)
4) Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine's networked medical devices, including PACS
5) Improved clinical outcomes as measured by specific radiology indicators on the length of stay (LOS) and other indicators for CAP and stroke

Potential benefits of the three-phase project included:

- Demonstration of radiology service management at remote locations
- Information on the impact of PACS technology on clinical outcomes for CAP and stroke
- Demonstration of secure teleradiology services at remote locations

The project's relevance to the military is related to its capacity to:

- Simulate the military's management of radiology services in remote, noncombat settings
- Validate ARSAM security architecture for PACS
- Ensure availability of high quality radiological services for military personnel, reserve personnel, and dependents

Project Period Deliverables and Results

All deliverables for this project period were met. During the period from September 29, 2005 to April 28, 2006:

- PACS equipment became fully operational at all four community hospitals (Eupora, Pontotoc, West Point, and Iuka sites)
- Radiology staff at all four sites were thoroughly training
- Data collection and analysis continued (see results below)
- Network vulnerability assessment and penetration tests were completed (see results below)

Key Research Accomplishments

- **Research Area: Impact of PACS on efficiency of radiologists as measured by performance indicators**

- Dramatic reductions were noted in Report Turnaround Time, the time that elapses following completion of the procedure and receipt of the radiologist's interpretation of the image, pre- and post-installation of PACS capabilities. At the hospitals in Eupora and Pontotoc, the wait for interpretations decreased from averages of 17 hours to less than two hours. Refer to Figure 1 on following page.

Figure 1
Report Turnaround Time
(From completion of procedures to radiologists' interpretations)
(March 2004 thru August 2004 versus March 2005 thru August 2005)

	Turnaround Time (March 2004 thru August 2004)	**Turnaround Time (March 2005 thru August 2005)**
Pontotoc	13 hours	.5 hours
West Point	9 hours	1.8 hours
Eupora	17 hours	1.3 hours
Iuka	17 hours	1.8 hours

- **Research Area: Impact of PACS on costs for radiology support staff (film librarians and technicians) and film (Figure 2)**

- Two of the four hospitals experienced cost savings as a result of PACS implementation. Radiology technicians at Pontotoc and Eupora also doubled as film librarians, so their positions were maintained when PACS was introduced.

Figure 2
Cost Reduction
(February 2005 through January 2006)

	Film Cost Reduction	**Personnel Reduction/ Salary Savings**
Pontotoc		
West Point		
Eupora		
Iuka		

- **Research Area: Impact of PACS on satisfaction of radiologists, other medical providers, and patients as measured by satisfaction surveys (medical staff, radiologists, and consumers)**

a. Referring Physician Survey

- In each of the four categories of satisfaction questions, the cumulative score increased from the baseline survey in 2003 to post-PACS in 2006. Refer to Figure 3.
- Physician response rate increased from 11.8 percent in 2003 to 33.9 percent in 2006

Figure 3 - Referring Physician Survey Results

Referring Physicians	2003	2006
Scheduling & Registration - Time it takes to schedule outpatients - Responsiveness for urgent patients	3.65	4.33 - 4.25 - 4.42
Physician Needs - Availability of radiologists to review films - Timeliness of receiving preliminary reports - Timeliness of receiving final reports - Timeliness in completion of urgent exams - Report turn-around time for urgent patients	3.74	4.15 - 4.36 - 3.97 - 4.01 - 4.29 - 4.14
Patient Needs - Waiting time in the department - Customer service attitude & tech performance	3.72	3.97 - 3.57 - 4.37
Radiologists - Quality & accuracy of interpretation - Availability for consultation - Calling of positive reports to physicians	3.93	4.16 - 4.20 - 4.15 - 4.15

- To supplement the empirical data, which trends strongly to greater satisfaction with radiology services, physician respondents write-in comments are presented in Figure 4.

Figure 4
Referring Physician Survey Write-in Comments (2006)

Do you feel that the implementation of PACS has changed the way you treat patients? For example, if the turn around time for reports is faster, has this helped with your ability to diagnose and treat patients?
• Greatly improved. • No change. • Yes, I can pull of the films and look myself. • Much easier. • We do not have PACS. (NMMCI physician) • Very good service. Able to review exams very quickly without having to wait for film processing. Do not have to deal with films in office. (NMMCI physician) • Turnaround is faster. • I personally do not use PACS. (NMMCI staff physician) • Patients return to the office before reports are available, even in PACS. (Private physician) • Faster, convenient to review films and reports from many locations.

Do you feel that the implementation of PACS has changed the way you treat patients? For example, if the turn around time for reports is faster, has this helped with your ability to diagnose and treat patients?
• The faster, the better. • We are not on PACS yet. (NMMCI physician) • Much faster, especially in emergency department. • Quicker and more efficient to view films. • Easier to read images off of computer. • I have not had to fight with the file room personnel. • Not really a change. (NMMCI staff physician) • Great system. • Able to review tests more quickly and make treatment decisions a little more quickly. • Has greatly helped with timeliness of patient care. • This would be a great way to improve turnaround time. We could actually have the report the same day the patient is here. (NMMCI physician) • Yes, am now able to pull up old x-rays to compare with new x-rays. • PACS in the NICU has been great for expediting care of patients and accomplishing routine rounds, including consultation and teaching with the entire staff – when it works, which is almost all of the time – but when there are problems viewing films lost in the system, it is a disaster, greatly confounding care. (Private practice – Women's Hospital NMMC – NICU)

Comments on Referring Physician Survey:
Note that several NMMCI physicians stated that they do not use PACS. The survey was designed for responding to PACS services at NMMC-Tupelo and the four community hospitals; these NMMCI physicians work in the clinic system, which will receive PACS during the current project period. They will be resurveyed specifically about the impact of PACS on their practice.

b. Patient Satisfaction Survey

- NMHS switched its patient satisfaction survey company from PRC to Press-Ganey in 2005. Unfortunately, only one month (March 2005) of baseline patient satisfaction data with outpatient radiation services is available for just three (Pontotoc, West Point and Eupora) of the four community hospitals. The number of satisfaction surveys is low in March 2005 because a new survey system was being initiated. Based on these few surveys, it appears that patient satisfaction with the pre-PACS service was high and remains high (Figure 5).

Figure 5 - Patient Satisfaction Survey Results

MONTH	N: 2005	N: 2006	% Patients Very Satisfied 2005	% Patients Very Satisfied 2006
March	7	55	89.5	88.7
April	18	40	91.1	89.7
May	28	53	87.4	93.1
June	23		82.9	
July	24		92.9	
August	26		92.5	
September	23		91.6	

- **Research Area: Improved clinical outcomes as measured by specific radiology indicators on the length of stay (LOS) and other indicators for CAP and stroke.**

- At its community hospitals in Eupora, Pontotoc, and West Point, NMMC is monitoring clinical outcomes as they relate to the implementation of PACS for two conditions: community-acquired pneumonia (CAP) and ischemic stroke, which were selected due to their high base rates of incidence among admissions to community hospitals and because diagnosis and initial treatments of CAP and ischemic stroke are dependent upon radiological studies.
- Reviewers of the Phase 1 portion of this project (implementing PACS on the NMMC-Tupelo campus) recommended incorporation of process indicators that were relatively close to and dependent on PACS to more reliably assess its impact. The timing of the first dose of antibiotic was selected as the process indicator for CAP and the administration of tissue plasminogen activator (tPA) as the process indicator for ischemic stroke. As in Phase 1, overall outcome indicators (length of stay, mortality and cost) were also measured pre- and post-PACS implementation
- Refer to Figure 6 on the following page. NMMC-Eupora had the most patients diagnosed with CAP pre- and post-PACS (even with a 29% decline in the post-intervention period). This patient population also was the most similar (age and severity ranking) between the two assessment periods. During this timeframe, the radiologists' turnaround times dropped from 17 hours to 1.3 hours (88 minutes), and the median time from emergency department admission to administering antibiotics dropped from 176 to 98 minutes. This is well below the four hour (240 minute) goal for antibiotic administration and may have contributed to the slight decrease in LOS, 5.81 to 5.47 days (5.8%) and the significant decrease in mortality (3.96% to 1.39% (65% decrease)). The median cost of the admission also dropped slightly, from -- to --.
- The other two hospitals, West Point and Pontotoc, also had positive LOS, mortality and cost outcomes, but their patient populations were different (age and severity) between the two time periods and their change in median antibiotic administration time was not significantly different. West Point did not demonstrate any change in its median time to antibiotic administration. This facility has regular daytime on-site radiologist coverage

and experienced the least improvement in radiologist study turn-around time (9.0 to 1.8 hours: Figure 1). The regular presence of a radiologist may account for the lack of improvement on antibiotic administration, i.e., the availability of PACS did not change their practice sufficiently. In short, it is difficult to project if the implementation of PACS may have been associated with these positive outcomes.

Figure 6

CAP Outcome Analysis Table

	Number of pts.	Ave. pt age	Ave. pt severity	Median time to antibiotic (mins)	Ave. length of stay (days)	Patient mortality	Median Cost
EUPORA							
Pre-PACS (April-Sept 2004)	101	67	2.09	176	5.81	3.96%	
Post-PACS (April-Sept 2005)	72	61	2.04	98	5.47	1.39%	
PONTOTOC							
Pre-PACS (April-Sept 2004)	17	72	1.81	120	4.29	0.00%	
Post-PACS (April-Sept 2005)	37	65	2.19	115	3.84	0.00%	
WEST POINT							
Pre-PACS (April-Sept 2004)	51	66	2.08	120	6.67	7.84%	
Post-PACS (April-Sept 2005)	45	49	1.91	120	4.13	0.00%	

- Refer to Figure 7 on the following page. Only one hospital, West Point, administered tPA to one patient. It was during the post-PACS timeframe, but as noted earlier, West Point already had about 40 hours per week of on-site radiologist time, so it is impossible to attribute this tPA usage to the implementation of PACS. Although the numbers of stroke patients are low, based on this 6-month pre- and post- PACS implementation analysis, it does not appear that PACS has made an impact on the care of stroke patients with regard to tPA administration, the chosen process marker. Whereas mortality decreased in all three hospitals, the LOS and median costs of care decreased in the two hospitals that did not administer the tPA.

Figure 7

Stroke Outcome Analysis Table

	Number of pts.	Ave. pt age	Ave. sev ind	tPA adminis-tration	Ave. length of stay (days)	Patient mortality	Median Cost
EUPORA							
Pre-PACS (April-Sept 2004)	16	79	2.25	0	5.69	6.30%	
Post-PACS (April-Sept 2005)	15	82	2	0	3.56	0.00%	
IUKA							
Pre-PACS (July-Dec 2004)	4	71	2.5	0	3.75	25.00%	
Post-PACS (July-Dec 2005)	13	69	2.5	0	3.93	7.10%	
WEST POINT							
Pre-PACS (April-Sept 2004)	16	74	2.38	0	5.00	6.30%	
Post-PACS (April-Sept 2005)	19	68	2.11	1	6.47	0.00%	

Project Period Security Architecture Testing

- **Research Area: Identification of highly effective security architecture for networked PACS systems that can be replicated for Army Medicine's networked medical devices, including PACS**

- NMMC contracted Sword & Shield Enterprise Security, Inc. (Sword & Shield) to conduct a network vulnerability assessment and penetration test of NMMC's external and internal networks. The assessment examined NMMC's implementation of the Army Security Architecture for Medical (ARSAM), a defense-in-depth network security architecture for FDA-approved medical devices. NMMC is using ARSAM in its deployment of the PACS within its hospital information system network.
- From an external perspective, the overall security posture of the NMMC network was deemed to be satisfactory. The firewall and network devices provided an adequate level of protection to the NMMC internal network, and PACS network, from Internet-based threats.
- However, Sword and Shield was able to circumvent the ARSAM protections implemented at NMMC during the internal phase of testing by taking advantage of some PACS devices that were located outside of the protected enclave and also by taking advantage of other devices on the network which were not patched with all of the latest security patches or system/applications updates.

Reportable Outcomes

To date, no manuscripts, abstracts, grant applications, patents, etc. have been submitted that are direct results of this project.

Conclusions

Implementation of PACS technology on NMMC's campus in Tupelo and four community hospitals has yielded information of potential value to other health care agencies serving rural regions:

1. PACS technology is associated with dramatic decreases in radiological report turn-around in rural settings
2. At two of the four sites (50 percent), the introduction of PACS technology resulted in cost savings (personnel and film)
3. Physicians reported greater satisfaction with radiological services following introduction of PACS capabilities
4. Due to a change in the patient satisfaction survey tool, there is not enough reliable pre-PACS patient satisfaction data to determine if PACS has an impact on patient satisfaction.
5. Data analyzed to date does not support the hypothesis that the use of PACS technology increases the speed with which antibiotics are administered as indicated for CAP.
6. The low usage of tPA in the management of ischemic stroke makes it an unreliable process indicator for efficacy of PACS in the management of stroke.
7. Overall outcomes (length of stay, patient mortality and median cost) trended towards improvement in the post-PACS period for both CAP and stroke.
8. Network sensitivity and penetration testing revealed that ARSAM protections implemented at NMMC were inadequate and that additional precautions needed to be taken in the security system architecture

As required by the Research Technical Reporting Requirements, "So what?" Work completed during the first two phases of PACS implementation and research at NMMC does indeed have implications for rural hospitals/health systems and for the military. PACS technology has dramatically increased the turn-around time for radiological images and increased significantly the number of "first reads" made by radiologists rather than other physician specialists. While this speed may not impact indicated treatments (process indicators) for CAP or stroke, it may be associated with the trend towards improved outcomes in this study and/or may result in more positive process indicators and outcomes for other clinical diagnoses not currently under study. PACS technology will likely be instrumental in improving physician satisfaction with radiological services at other rural hospitals, which struggle to recruit and retain qualified health care providers. When contemplating implementation of PACS, some hospitals may be able to project cost savings from personnel or supply (film) budgets. The results of network sensitivity and penetration testing completed to date at NMMC suggest that ARSAM protections must be enhanced to guard patient data, which will guide other rural hospitals in the implementation and design of their PACS

systems. Test results are also of significance to the military's efforts to deliver radiological services from remote, noncombat sites to battlespaces.

The health system's experiences will be used to formulate recommendations for installation, implementation, and application of PACS systems, including highly effective security architecture. Data collected on indicators pertinent to clinical outcomes will be used to document the impact of PACS technology in civilian applications.

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Appendices

Not applicable